Yield and Quality of Wheat, Triticale, and Elytricum Forage in the Southern Plains

S. C. Rao,* S. W. Coleman, and J. D. Volesky

ABSTRACT

Hard red winter wheat (*Triticum aestivum* L.) is a major cool-season forage that couples with warm-season perennials to provide livestock feed in the Southern Plains. Productivity and quality of wheat forage declines in April, creating a forage deficit period until warm-season perennial grasses are available. Other cool-season annual grasses with different growth patterns may provide growth during this period to fill this forage deficit. A field experiment was conducted on Brewer silty clay (fine, mixed, superactive, thermic Udertic Argiustoll) from 1994 to1997 to compare seasonal forage production patterns and yield and quality of winter wheat, triticale (× *Triticosecale rimpaui* Wittm.) and × *Elytricum* spp. (*Triticum aestivum* × *Elytrigia* spp. 'OK-906'). Aboveground whole-plant biomass during late fall and early spring were greater for wheat than elytricum, but this trend was reversed in late spring and early summer. Average growing degree days to reach physiological maturity were 2500, 2670, and 3100 for wheat, triticale, and elytricum, respectively. Averaged across years, triticale and elytricum reached maturity 8.5 and 28 d after wheat, respectively. At physiological maturity, differences in biomass accumulation between wheat and triticale were minimal, but elytricum at physiological maturity produced 22% more total biomass, 3.5% less grain, and 28% greater straw yield as compared with wheat. Differences in straw in vitro dry matter disappearance (IVDMD) among species were minimal. Because of its prolonged vegetative-growth phase compared with wheat or triticale, elytricum has the potential to fill the late spring forage deficit period and reduce supplemental feed cost for livestock.

A BASIC GOAL of many grazing programs is to provide high quality forage year round to reduce the costs of storing and purchasing concentrate feeds. No single crop has the potential to provide forage year round. Therefore, new or existing forage species that have the ability to provide forage for grazing over an extended period need to be developed and evaluated. Hard red winter wheat is a major source of forage for livestock in the southern Great Plains. Stocker calves (*Bos* spp.) are placed on the wheat in fall, usually in November. Wheat can be used in a graze–out or graze–grain system. *Graze–out* refers to maintaining the calves on wheat until it senesces in summer. Under a graze–out systems forage biomass and quality declines around the middle of April. In the *graze–grain* system, calves are usually removed during March (at jointing) allowing the wheat to produce grain. If cattle are removed at jointing, grain can be harvested with only a slight depression in yields (Redmon et al., 1995). Either option leaves a forage deficit period until warm-season perennial grasses are available for grazing in mid summer.

Sapra et al. (1973) reported that forage production of triticale, a cross between wheat and rye (*Secale cereale* L.), was equal to that of wheat, barley (*Hordeum vulgare* L.), and rye. Triticale also was productive later in the spring than wheat in the southeastern USA. Brown and Almodares (1976), Finker and Fuehring (1974), and Prato et al. (1971) observed greater fluctuation in grain yield and protein in triticale than was reported for wheat and other small grains in other geographical areas. Forage quality of triticale, from boot to the soft-dough growth stage, was also lower than wheat forage (Tidwell et al., 1987).

Crossing wheat with perennial wheatgrass (*Elytrigia* spp.) produced a hybrid known as elytricum (Morris and Sears, 1967), later classified as × *Elytricum* spp. California plant breeders first introduced elytricum in the 1930s in hopes of developing perennial wheat. Later, Oklahoma State University researchers utilized elytricum to breed disease resistance characteristics into Oklahoma wheat (E. Smith, 1998, personal communication). Subsequent crosses of elytricum with, and back-crosses to, wheat were used to develop OK-906 cultivar elytricum. Availability of information on forage production patterns and nutritive value of OK-906 in the southern Great Plains region is minimal. Our objective was to evaluate seasonal forage production patterns and quality of elytricum, triticale, and winter wheat under dryland conditions.

MATERIALS AND METHODS

Field experiments were conducted for four growing seasons at the Grazinglands Research Laboratory, USDA-ARS, near El Reno, OK. Winter wheat, triticale, and elytricum were seeded on 7 Sept. 1993, 14 Sept. 1994, 11 Oct. 1995, and 9 Sept. 1996 into conventionally tilled plots. Seed was drilled at the rate of 100 kg ha^{-1} with a 20-cm row spacing in 3 by 30 m plots with 1-m alleys between plots. All plots were free of weeds. Before seeding, 50 kg of N ha^{-1} as urea was broadcast and incorporated with shallow disking. This was followed by 100 kg N ha^{-1} broadcast in the spring (March). The study was arranged in a randomized complete block design with three replications. Whole plant samples were hand-clipped randomly from three 30-cm rows (total of 90 cm) every 30 d after seeding until physiological maturity. Samples were taken at a new location at each sampling date and cut to a height of 2 cm. In 1995, the first sample was collected 60 d after seeding

USDA-ARS, Grazinglands Research Laboratory, 7207 W. Cheyenne St., El Reno, OK 73036; S. W. Coleman, USDA-ARS, STARS, 22271 Chinsegut Rd. Brookeville, FL 34601-4672; and J.D. Volesky, Univ. of Nebraska, West Central Research and Extension Center, Rt. 4 Box 46, North Platte, NE 69101. Received 18 Nov. 1999. *Corresponding author (srao@grl.ars.usda.gov).

Published in Crop Sci. 40:1308–1312 (2000).

Abbreviations: IVDMD, in vitro dry matter disappearance; N, urea N.

Table 1. Number of days and growing degree days (GDD) from seeding to physiological maturity of three species.

	1993–1994		1994–1995		1995–1996		1996–1997		SEM†	
	Days	GDDs	Days	GDDs	Days	GDDs	Days	GDDs	Days	GDDs
Wheat	282	2668	274	2580	241	2161	279	2539	9	112
Triticale	282	2668	287	2836	252	2426	289	2765	9	89
Elytricum	302	3177	299	3107	280	2765	307	3179	6	99
SEM	6	170	7	152	11	112	28	138		

† Standard error of the mean.

due to exceptionally cool and dry conditions. Growing degree days were calculated by averaging maximum and minimum temperature (°C) for each day minus 3°C, which is the minimum temperature for wheat growth (Austin and Jones, 1975). Plant samples were dried in a forced-draft oven at 65°C for at least 60 h, weighed, and ground (1-mm screen) before determining N concentration by complete combustion (Leco CHN-1000, Leco Corp., St. Joseph, MI), and IVDMD using a modification of two-stage technique (Monson et al., 1969).[1] At physiological maturity harvested samples of each species were separated into seed and straw and N and IVDMD analyses were conducted on both plant components.

All treatments were fixed in space and repeated on the same plot throughout the entire study period. Data for each year were analyzed as a split-plot in time, with species arranged in a randomized complete block design that was assigned the first year and not randomized in the subsequent years. Harvest date was analyzed as a repeated measure. Species were judged to be different if *F* values were statistically significant at $P <$ 0.05 level. Mean separations were done by lease significant differences using pooled mean square error. Year effects and the year × species interactions were statistically significant, so data were analyzed and the results presented by year.

[1] Mention of a specific proprietary product does not constitute a recommendation by the USDA-ARS and does not imply their approval to the exclusion of other suitable products.

RESULTS AND DISCUSSION

Growing degree days and days to reach physiological maturity varied among species. Average numbers of growing degree days to reach physiological maturity were 3100, 2670, and 2500 for elytricum, triticale, and wheat, respectively. Average days to reach physiological maturity were increased by 28 and 8.5 d for elytricum and triticale, respectively, when compared with winter wheat (Table 1). Elytricum reached maturity later than wheat and triticale in all 4 yr. When examined across years, as expected, the number of growing degree days was a more consistent predictor of physiological maturity than days after seeding, which was due to variable climatic conditions.

Growing Season Aboveground Biomass, Nitrogen, and In Vitro Dry Matter Disappearance

Seasonal biomass accumulation for all three species is presented with LSD values ($P < 0.05$) for only sampling dates in which significant differences were observed (Fig. 1). Total aboveground biomass production during the1995-1996 growing season was lower during fall and winter than in other years. Lower fall biomass accumula-

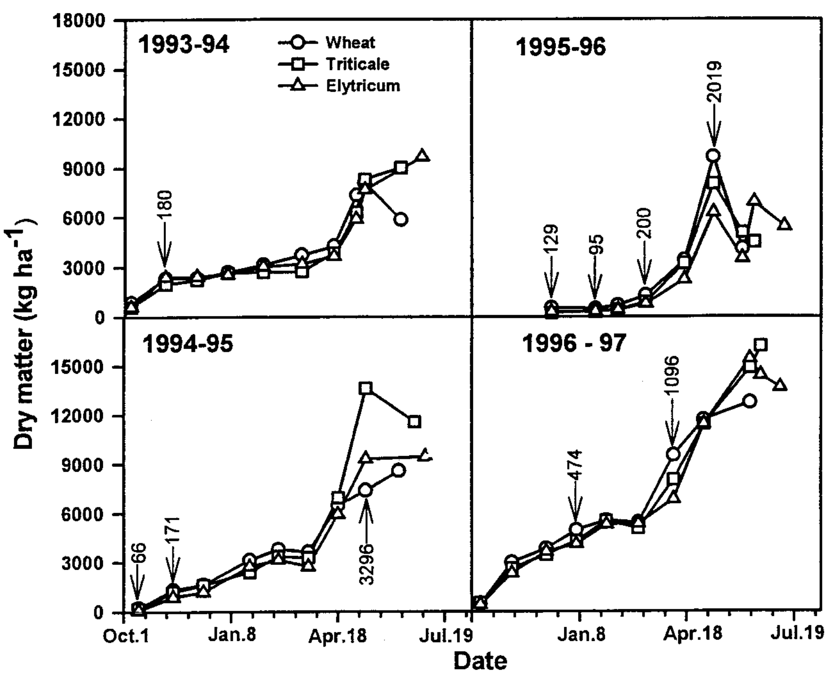

Fig. 1. Seasonal dry matter accumulation and precipitation patterns during 1993 to 1997 growing seasons. LSD values at 0.05 level represent statistically significant sampling dates.

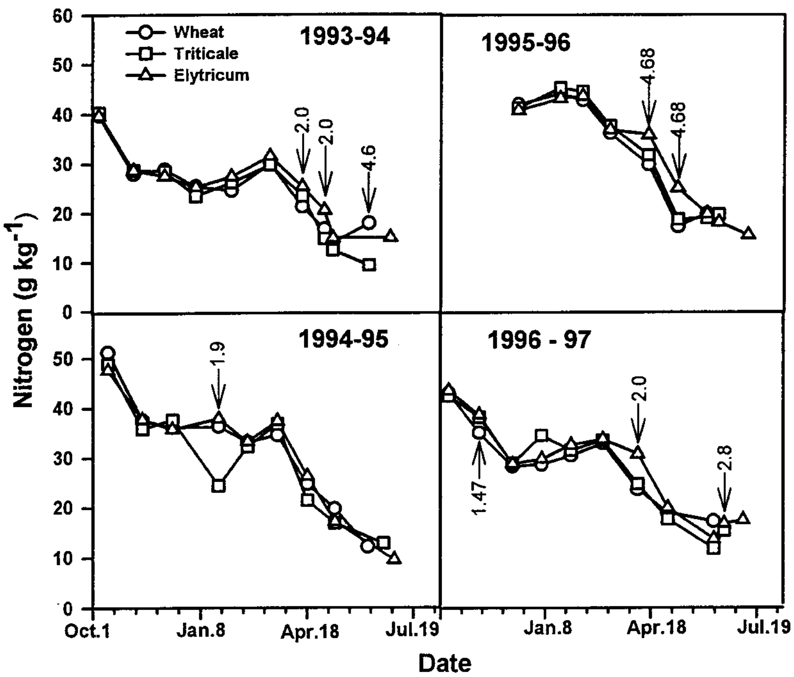

Fig. 2. Nitrogen concentrations in the aboveground biomass from seeding to harvest during 1993 to 1997 growing seasons. LSD values at 0.05 level represent statistically significant sampling dates.

tion in the 1995-1996 was attributed to low precipitation and cool temperatures. Total precipitation received during 1995-1996 was 508 mm, or considerably less than the average of all 4 yr of 831 mm. Below-average precipitation and warmer temperatures in the early spring of 1996 hastened maturity for wheat by 33 to 41 d, triticale by 30 to 35 d, and elytricum by 19 to 27 d compared with other growing seasons. Dry conditions are known to reduce the length of the wheat's growing period (Shutt and Hamilton, 1934). Keim and Kronstad (1981) reported a 55% reduction in the tiller number of water-stressed plants compared with well-watered controls. In our study the combination of a dry fall and winter with warmer spring temperatures affected total biomass production during 1995-1996 (Fig. 1). Biomass accumulation for wheat and elytricum during late fall and winter were similar in 1993-1994 and 1995-1996, whereas wheat and triticale produced more biomass than elytricum dur-

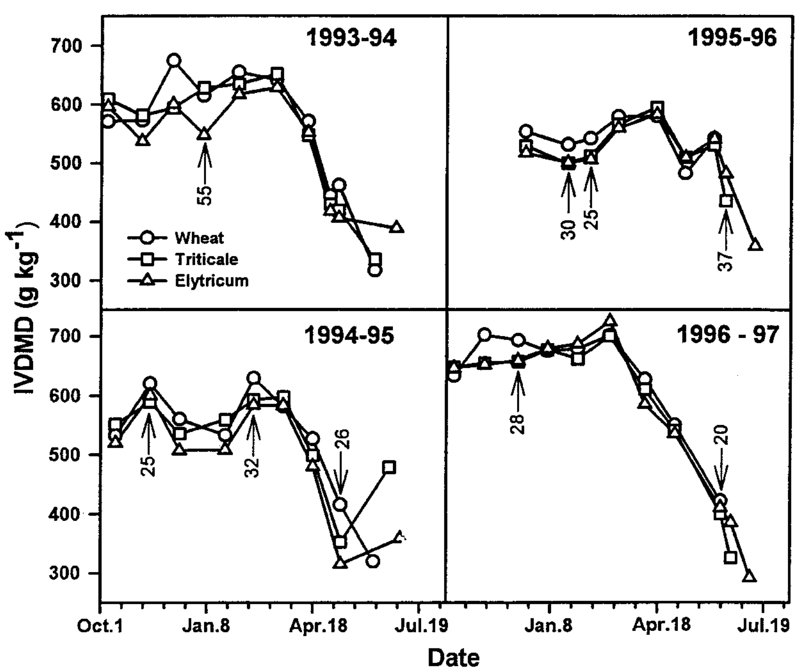

Fig. 3. In vitro dry matter digestibility (IVDMD) concentrations in the aboveground biomass from emergence to harvest during the 1993 to 1997 growing seasons. LSD values at 0.05 level represent only statistically significant sampling dates.

Table 2. Seed and straw biomass and N and in vitro dry matter disappearance (IVDMD) concentration for whole plant, seed, and straw of three species at physiological maturity during the 1994 to 1997 growing seasons.

Year	Species	Dry matter		Nitrogen			IVDMD		
		Seed	Straw	Whole	Seed	Straw	Whole	Seed	Straw
		kg ha^{-1}		g kg^{-1}					
1994	Wheat	708	5 152	18.0	25.0	17.1	315	793	250
	Triticale	1859	7 163	9.5	18.4	7.2	342	809	214
	Elytricum	1280	8 384	15.6	19.9	15.0	393	863	327
	LSD (0.05)	59	2 528	9.2	10.4	11.1	233	60	254
1995	Wheat	1844	6 735	12.3	24.1	9.1	319	715	211
	Triticale	5189	6 375	11.8	21.7	6.0	477	809	210
	Elytricum	1650	7 792	9.8	25.2	6.6	349	882	239
	LSD (0.05)	1796	3 536	3.0	2.4	4.2	68	41	24
1996	Wheat	1534	2 574	20.1	27.6	15.7	543	866	351
	Triticale	1290	3 213	19.9	31.1	15.4	435	734	315
	Elytricum	1395	4 037	15.8	21.3	14.0	359	731	229
	LSD (0.05)	567	760	1.8	6.5	1.2	31	64	69
1997	Wheat	2152	10 594	16.7	22.1	15.6	422	833	338
	Triticale	3425	12 761	14.9	25.7	12.1	325	721	221
	Elytricum	1685	11 982	17.0	29.6	15.4	292	722	231
	LSD (0.05)	1424	3 688	3.6	2.0	4.3	38	23	40

ing the same period in the 1994-1995 and 1996-1997 growing seasons. Triticale biomass production peaked in early to middle of June, when it tended to be similar to or greater than that of wheat, and was greater than that of elytricum in 1994-1995 (Fig. 1). During the 1995-1996 growing season, elytricum accumulated 53% more biomass in late June than triticale ($P < 0.10$) and wheat, which were at physiological maturity.

While some statistical differences in seasonal biomass production among species were evident (Fig. 1), the differences were not biologically significant with regard to feed supply. Predictably, biomass was larger in wheat than triticale and elytricum when wheat was in the reproductive phase and the other two species were still in the vegetative stage. At anthesis, most annuals translocate nutrients from leaves and stems into seeds (Rao and Croy, 1972). Although late-maturing species had less total biomass in the middle of April, they continued to accumulate biomass after wheat had matured.

Nitrogen concentration in the aboveground plant parts varied among sampling dates within each growing season. During some harvests in the spring of the 1993-1994, 1995-1996, and 1996-1997 growing seasons, N concentration was greater for elytricum than for wheat or triticale (Fig. 2). On the same dates that N concentration was higher in elytricum, total biomass of elytricum was reduced (Fig. 1 and 2). Thus, the greater relative N concentration for elytricum may be attributed to a dilution of available N in wheat and elytricum. Patterns of total N accumulation (biomass $\times$ N percentage) in the aboveground biomass were similar to biomass accumulation (data not shown); however, total accumulation of N for wheat and elytricum during April 1994 was greater than triticale. Total accumulation of N in wheat was greater during spring of 1995-1996 and 1996-1997, but these differences disappeared as growth continued. This suggests that even though elytricum had slow early-season growth, the amount of N ultimately accumulated in the aboveground parts was similar among all species for all growing seasons except 1995-1996.

The IVDMD of wheat was generally greater than that of elytricum and triticale during the late fall and early spring (Fig. 3). At physiological maturity of wheat, elytricum biomass was more digestible than triticale in all years except 1994-1995. This suggests that during its prolonged vegetative period, elytricum continued to increase in IVDMD, whereas late in the growing season, triticale had senescing leaves and a higher fiber content resulting in lower IVDMD. In vitro dry matter digestibility decreased as the plants matured, probably due to greater indigestible fiber content (Nelson and Moser, 1994).

In vitro dry matter disappearance yield (IVDMD percentage $\times$ biomass) was greatest for wheat until May (anthesis), followed by triticale (data not shown). However, elytricum continued to produce digestible dry matter until the middle of June because of extended vegetative growth compared with wheat and triticale. Patterns for digestible dry matter by elytricum were similar to N accumulation patterns, with both declining as the plants approached physiological maturity.

Aboveground Biomass, Nitrogen, and In Vitro Dry Matter Disappearance at Physiological Maturity

Aboveground biomass accumulation at physiological maturity for elytricum was 65% greater in 1994 and 32% greater in 1996 as compared with wheat (Table 2). This occurred because elytricum produced more straw in both years as compared with wheat. Seed yield for wheat and elytricum were similar and lower than triticale in the 1994 and 1995 growing seasons. Greater straw yield for elytricum in 1994 and 1996 probably was due to its being crossed with a perennial grass. Perennial wild grasses are notoriously poor and erratic seed setters. Many perennial grasses do not emphasize seed production as do annuals. Wheatgrass seeds are smaller than the current wheat cultivars and may have contributed to lower seed yield (Harlan, 1992). Triticale produced higher seed dry matter in three of the 4 yr of study as compared with elytricum.

In general, N concentration in the aboveground plant samples at physiological maturity was not significantly different in 1994, 1995, and 1997, but in 1996 N concentration was greater in wheat and triticale than in elytricum (Table 2). This decrease in N concentration for elytricum in 1996 could be attributed to increased biomass accumulation and a dilution of total N uptake. Nitrogen concentration in seed at final harvest also varied among years and was lowest in triticale during 1995, perhaps due to increased seed yield. In 1996, seed N concentration was greater for wheat and triticale and might be attributed to early maturity and lower growing degree days under dry conditions. Seed N concentration in 1997 was greater for elytricum and triticale than for wheat. Straw N concentrations were similar for all species in three of the four growing seasons. In 1996, low N concentrations in straw of elytricum could have been due to increased precipitation in July that may have caused leaching of soluble compounds from green vegetation. Although, elytricum straw yields were higher than wheat in 1994 and wheat and triticale in 1996, lower N concentrations resulted in total N accumulation that was similar for all species.

In vitro dry matter disappearance also varied among years and species. Values for wheat and elytricum were similar at physiological maturity in 1994 and 1995, but whole-plant IVDMD for triticale (1995) and triticale and wheat (1996) were greater than for elytricum (Table 2). Rao (1989), Schrieber and McDowell (1985), and Collins (1985) reported that rain or wetting of wheat and alfalfa (*Medicago sativa* L.) reduced hay quality by reducing IVDMD and increasing neutral detergent fiber. Low IVDMD values for whole plant elytricum in 1996 could be attributed to higher precipitation, and delayed maturity.

In vitro dry matter disappearance for all species aboveground biomass were very low at physiological maturity. Triticale in 1995 and 1996 and wheat in 1997 were the only samples exceeding 40%. Increased seed yield could improve whole plant digestibility. Because seed digestibility was three to four times greater than that of straw, increased seed yield could improve whole-plant digestibility. Only triticale in 1995 exhibited both higher seed yield and digestibility.

CONCLUSIONS

These results suggest that prolonged vegetative growth of elytricum has the potential to provide high-quality forage for 4 wk longer than wheat, the traditional forage, thereby minimizing the forage deficit gap between wheat and warm-season perennial grasses. Generally, fall and winter production and quality of elytricum forage is similar to wheat and triticale forage. Therefore, elytricum forage offers all the grazing benefits of winter wheat, plus a longer growing season. Livestock producers using the current winter wheat production system in the Southern Plains have the option to seed elytricum, particularly on pastures designated for graze–out type of management. Volesky et al. (1994) reported that in preliminary grazing trails, the graze–out period of elytricum was an average of 40 d longer than wheat pasture and supported a 34% increase in stocking rate. Due to lower seed production and lack of value of elytricum seed, wheat should be planted on land designated for both pasture and grain production.

ACKNOWLEDGMENTS

The authors express their appreciation to Russ Bouseman and Larry Pellack for technical assistance, and special gratitude is expressed to T. W. Popham for his assistance in statistical analyses.

REFERENCES

Austin, R.B., and H.G. Jones. 1975. The physiology of wheat. p. 20–73. *In* Plant Breeding Inst. Annual report 1974. Plant Breeding Inst., Cambridge, UK.

Brown, A.R., and A. Almodares. 1976. Quantity and quality of triticale forage compared to other small grains. Agron. J. 68:264–266.

Collins, M. 1985. Wetting effects on the yield and quality of legume and legume–grass hay. Agron. J. 77:936–941.

Finker, R.E., and H.D. Fuehring. 1974. Triticale production in New Mexico. Agric. Exp. Stn. Bull. 625. Las Cruces, NM.

Harlan, J.R. 1992. Crops and man. ASA and CSSA, Madison, WI.

Keim, D.L., and W.E. Kronstad. 1981. Drought response of winter wheat cultivars grown under field stress conditions. Crop Sci. 21: 11–15.

Monson, W.G., R.S Lowrey, and I. Forbes. 1969. In vivo nylon bags Vs. two stage in vitro digestion: Comparison of two techniques for estimating dry matter digestibility of forages. Agron. J. 61:587.

Morris, R., and E.R. Sears. 1967. The cytogenetics of wheat and its relatives. p. 19–87. *In* K.S. Quisenberry and L.P. Reitz (ed.) Wheat and wheat improvement. Agron. Monogr. 13. ASA, Madison, WI.

Nelson, C.J., and L.E. Moser. 1994. Plant factors affecting forage quality. p. 115–154. *In* G.C. Fahey (ed.) Forage quality, evaluation, and utilization. ASA, CSSA, and SSSA, Madison, WI.

Prato, J.D., C.O. Qualset, and J.P. Gustafson. 1971. Triticale. Crops Soils 23:18–19.

Rao, S.C. 1989. Regional environment and cultivar effects on the quality of wheat straw. Agron. J. 81:939–943.

Rao, S.C., and L.I. Croy. 1972. Protease and nitrate reductase seasonal patterns and their relation to grain protein production of "High Vs. Low" protein wheat varieties. Agric. Food Chem. 20:1138–1141.

Redmon, L.A., G.W. Horn, E.G. Krenzer, and D.J. Bernardo. 1995. A review of livestock grazing and wheat grain yield: Boom or Bust? Agron. J. 87:137–147.

Sapra, V.T., G.C. Sharma, J. Hughes, and R.R. Bradford. 1973. Triticale, a wheat–rye hybrid. J. Tenn. Acad. Sci. 48:59–61.

Schreiber, J.D., and L.L. McDowell. 1985. Leaching of nitrogen, phosphorus, and organic carbon from wheat straw residues: I. Rainfall intensity. J. Environ. Qual. 14:251–255.

Shutt, F.T., and S.N. Hamilton. 1934. The quality of wheat as influenced by environment. Emp. J. Exp. Agric. 2:119–138.

Tidwell, E.K., K.D. Johnson, J.H. Cherney, and H.W. Ohm. 1987. Forage yield and quality of soft red winter wheat and a winter triticale. Appl. Agric. Res. 2:84–88.

Volesky, J.D., C.M. Taliaferro, and E. Smith. 1994. Evaluation of elytricum as a cool-season forage. Field Day Rep. USDA-ARS Forage and Livestock Res. Lab., El Reno, OK.